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A NUCLEAR POWERED AIR CUSHION FREIGHTER FOR THE 1980'S

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ABSTRACT

A design for a transoceanic, dry cargo-carrying freighter is suggested; its use and operation in port are discussed. With a gross weight of 4500 metric tons (5000 tons), more than 50 percent of which is cargo, it will cruise at 50 meters per second (100 knots) in waves 2.4 meters (8 ft) high. Its peripheral jet-flexible skirt air cushion concept and air thrustors will let the freighter go over waves 8 meters high at reduced velocity. Power comes from a 1280 megawatt, helium-cooled thermal reactor. It could dock at any major port in the world, but because it needs no surface contact, it could also travel inland to land-locked ports. A modular terminal design and methods of cargo transfer are suggested. The concept of cargo containerization influences both the freighter and terminal design.

A NUCLEAR POWERED AIR CUSHION FREIGHTER FOR THE 1980'S

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SUMMARY

A design for a transoceanic dry cargo-carrying air cushion freighter is suggested and its use and operation in port are discussed. The freighter has a gross weight of 4500 metric tons (5000 tons) more than 50 percent of which is cargo. It could cruise at 50 meters per second (100 knots) through 2.4 meter ocean waves and operate in 8 meter waves at reduced velocity. The freighter need no surface contact for its operation because it uses the peripheral jet-flexible skirt air cushion concept and air thrustors.

Studies of nuclear airplane reactors indicate that powerplant weight can be decreased at least tenfold from marine nuclear reactors. Hence, power for the supportive air cushion and the thrust comes from a 1280 megawatt, gas-cooled thermal reactor similar to those designed for a nuclear airplane.

The freighter could dock at any major port in the world but it could also travel over "flat" land - that is, land with obstacles less than 6 meters high and deep gulleys less than 45 meters wide. Hence, it could cross ice, mud, shallow water, or marsh to terminals several miles inland. Its access to barren or unused flat land would permit new freedom in port location and design. The use of inexpensive land and the capability of loading and unloading while docked on land could reduce the cost of terminal facilities and indirect operating costs. To illustrate this freedom one port-city design and one modular terminal design are presented. The concept of cargo containerization, its present use, its importance to this freighter, and methods of cargo transfer are discussed. By 1980 it would take a fleet of more than 250 such freighters to carry 5 percent of the world's dry cargo.

INTRODUCTION

By the 1980's a marriage of air cushion vehicle (ACV) technology and light-weight nuclear powerplant technology could dramatically affect transoceanic commerce.

Only a dozen years ago (1959) the English Channel was first crossed by an ACV. Just 3 years before that the first "table top" demonstration of the ACV principle occurred. And just a few years later there was world wide application of the vehicle. Since 1965 ACVs have been used for a

variety of tasks - experimental, commercial, and military - all over the world. And currently there are visions and studies of large (multi-thousand ton) cargo-carrying ocean-going ACVs. The development of the ACV has been remarkable.

But, ACVs consume large amounts of energy - more energy per mile than similar gross weight aircraft, for example. If large ACVs were to use chemical fuel then the large amounts of fuel that must be carried will limit the payload and the range. Even nuclear marine powerplants cannot help because they are too heavy. However, nuclear aircraft studies at Lewis (refs. 1 through 3) indicate that the weight of mobile nuclear powerplants might be reduced by at least a factor of ten.

This potential weight reduction may provide both a technological and an economic break, paving the way for fleets of large nuclear powered ACV freighters hauling transoceanic cargo after 1980. Large means a gross weight of several thousand tons. The technical parameters of the nuclear-powered vehicles are discussed in references 4 and 5; their economic performance is outlined in reference 6.

The purpose of this study is to describe the general features of a large nuclear air cushion vehicle (NACV) as an ocean-going freighter and then to discuss cargo handling and docking techniques and the layout of a city-port and modular terminal adapted to such freighters. Emphasis is on the use of the freighter more than on the design.

The particular ACV described in this report uses the peripheral jet-flexible skirt air cushion concept. It is nuclear powered, has a gross weight of 4500 metric tons (5000 tons), and can travel at 50 m/sec (100 knots) with a clearnace height (daylight gap) of about 0.3 m (1 ft). The flexible skirt is 7.6 m (25 ft) high; the rigid structure of this ACV would thus be about 7.9 m above the water.

There is a strong reason for studying NACVs as transoceanic cargo-carriers - economics. A foreign trade forecast (fig. 1) indicates that world dry cargo tonnage is increasing by 4.5 percent per year. Thus, by 1980 the annual world dry cargo tonnage will increase by more than 50 percent - to 1.3 billion metric tons (1.4 billion tons); by 1985 it may have doubled - to about 1.6 billion metric tons. By comparison the U.S. dry cargo trade tonnage is increasing at only 2 percent per year - from 270 million metric tons (300 million tons) now to only about 360 million metric tons in 1980 (ref. 7). One other statistic: the U.S. Flag Fleet in 1968 carried only about 7 percent of our own dry cargo tonnage (ref. 8). The economic opportunity for cargo vehicles is large.

Presently sea freight costs about 0.3¢/metric ton-km (1/2¢/ton-n. mi.); overseas air freight costs about 12¢/metric ton-km (20¢/ton-n. mi.) (ref. 7). In spite of this large unit price difference a growing percentage of high value cargo is going by air. In fact, cargo valued at more than \$550 per

metric ton (\$500 per ton) (35% of the free world's exports) could be potential cargo for chemically powered ACVs of the captured air bubble type (ref. 9).

A potential hauling cost rate of about 1.2¢/metric ton-km (2¢/ton-n. mi.) has been suggested for large NACVs (ref. 6). With a speed of 50 m/sec, such a NACV would fit nicely into a present carrier gap in overseas transportation (fig. 2).

LARGE AIR CUSHIONED VEHICLES

Since 1965 ACVs have been in commercial operation in San Francisco, Scotland, England, and West Germany; in U.S. military operations in Vietnam; and in test operations in Alaska, Greenland, Borneo, South America, North Africa, and Japan. The largest ACV now operating (4 are in ferry service across the English Channel) is the SR N4 (fig. 3). It weighs 150 metric tons (168 tons) and can travel at 33 m/sec (65 knots).

However, in the U.S. during 1971, two 90 metric ton (100 ton) ACVs (an artist's conception of one is shown in fig. 4) are to begin their sea trials (ref. 10). They are the first approaches to design targets of 3600-4500 metric ton (4000-5000 ton) craft.

Small ACVs appear to be technically and economically practical - enough that "5000 tonners" are being seriously studied. In fact, most of reference 9 is a technical and economic evaluation of a large chemically powered ACV - 5000 metric ton (5500 tons). This ACV used the relatively efficient captured air bubble (CAB) concept. But, the CAB concept has the disadvantage of requiring water surface contact to maintain the bubble. This not only restricts the vehicle to use on water but also introduces major problems of structural integrity when travelling at high speed. Reference 11 is a comparative study of 5 ACV concepts for chemical vehicles up to 9000 metric tons (10 000 tons).

The Merchant Marine studies (refs. 9 and 12) of multi-thousand ton ACVs assumed the use of chemical fuel. But, with chemical fuel (especially as the range increases) the efficiency of the power system is very important - because fuel displaces payload.

The use of nuclear fuel, however, would offer a great advantage - an abundance of energy. The efficiency of the power system becomes somewhat less important than if a chemical fuel were used. The use of nuclear power would allow an almost unlimited range without reduction in payload and it also would permit a larger payload fraction for the long ranges which in turn would permit lower operating costs. From reference 4, for ranges greater than 3700 kilometers (2000 n. mi.) the nuclear ACV shows a clear economic advantage over the chemical ACV. In fact, for a range of 7400 kilometers (4000 n. mi.) the total operating cost of chemical ACVs

would be about 3 times that of nuclear ACVs. Furthermore, the range of a NACV using nuclear aircraft technology should be greater than 1.5 million kilometers between refuelings.

Because of this energy abundance another ACV concept - the peripheral jet with flexible skirt - becomes attractive. And an impressive new freedom can be obtained - the freedom from surface contact. This means the ACV would not be restricted to deep water or even to water at all. The ACV could go over swamp, ice, sand, mud, or coastal plain. The only terrain restriction is that the surface be reasonably flat: solid obstacle height less than 85 percent of flexible skirt height, deep gulley width less than one-third the air cushion length, and extended surface slopes of only a few degrees. This substantial freedom in selecting terminal sites would contribute to lower indirect operating costs.

DESCRIPTION OF FREIGHTER

A 4500 metric ton (5000 ton) nuclear powered ACV is shown schematically in figure 5. This ACV concept - peripheral jet with flexible skirt - does not require aerodynamic lift. Furthermore, it needs no surface contact to either maintain the air cushion or propel the vehicle - a distinct advantage. Its specifications (Table I) are based largely on the designs described in references 4 and 5.

The vehicle has a length of 137 m (450 ft), a beam of 76.2 m (250 ft) and height, excluding the tail section, of 19.8 m (65 ft). Its cushion pressure is 48 newtons/meter² (100 lb/ft²). The vehicle is designed to cruise at 50 m/sec (about 100 knots) with a 0.3 m (1 ft) clearance above a flat surface. Adding this clearance to the height of the flexible skirt (7.6 m) means the rigid structure of the freighter will be 7.9 m (26 ft) above a flat surface. The bottom of this rigid structure is the flotation tanks under the craft. These compartmentalized tanks are about 1.8 m high (providing about 200% buoyancy) and are completely surrounded by the skirt. (The buoyance of the skirt is neglected.) To provide stability when the freighter is operated as a displacement vessel, there are two groups of tanks - from 7.6 m to 30.5 m on each side of the craft center line.

Retractable landing skids or resting pads will fasten to the bottom of the flotation tanks. When the vehicle is parked the extended pads can rest on support posts, while the vehicle is loaded, discharged, serviced or repaired. Without support posts, the extended pads would still prevent the skirt from carrying the full weight of the freighter (see fig. 5).

The air cushion is provided by 6 lift fans, each of which is 4 m (about 13 ft) in diameter and has a 7.5 MW (10 000 horsepower) steam turbine to drive it. The lift fans produce a peripheral air jet directed down and in 30 degrees from the vertical. The geometry of the flexible

skirt (consisting of bag and replaceable fingers) and the airflow through it are shown in figure 6. To provide stability when on-cushion, the cushion may have several partitioned cells.

The vehicle is propelled by 6 thrust fans mounted in the stern. Each of the thrust fans is 7.6 m (about 25 ft) in diameter and uses a 35.4 MW (47 500 horsepower) steam turbine. Thrust deflectors may be inserted into the slipstream of the two outer thrustors to provide braking and maneuverability at slow speeds.

When underway the freighter would be steered by rudders on the fore and aft sections; when docking or hovering it would be maneuvered using air deflectors inserted into the slipstream of the thrustors.

A schematic for the power system is shown in figure 7. Air for the cushion and for propulsion enters through louvers on the top of the craft. The air is pressurized by the fans and then passed over condensers which contain the turbine exhaust steam. The warmed, pressurized air from the lift fans goes into a plenum from which it is distributed to the peripheral jets.

The power for this ACV freighter is supplied by a nuclear reactor (fig. 8). This reactor generates 1280 MW of thermal power; it is cooled by helium which is then the heat source for the boiler. The reactor core is water moderated and is shielded by a combination of borated water and tungsten or depleted uranium. The shielding reduces the radiation dose level to that permissible for general population exposure - 0.25 millirem per hour 6.1 (20 ft) from the outer surface of the shield.

The reactor system is designed to minimize the possibility of fission product release during major accidents (refs. 1 through 3). One favorable factor is that an ACV accident would involve maximum speeds of only about 50 m/sec. A nuclear aircraft accident - for which this reactor safety technology has been designed - could involve speeds up to 300 m/sec. So, the problem of preventing reactor containment vessel leaks on impact of this ACV is much less severe than for an airplane.

In case of a reactor shutdown the steam cycle may continue to operate the lift and thrust fans at reduced power by means of a gas fired boiler which uses reserve chemical fuel. Enough fuel is carried for a 925 kilometer (500 n. mi.) range.

Figure 9 is an artist's concept of this freighter, underway with full cargo.

DESCRIPTION OF CARGO

The cargo area of the freighter is U-shaped and 9.1 meters (30 ft) high (figs 5 and 9). To improve the aerodynamic profile and protect the

cargo, the cargo area can be covered by fiberglass sections when underway. The freighter can be loaded or unloaded by ramp or crane from the front or side. It can be driven under pre-loaded docks or huge pallets - much like a fork lift.

Specifications

The payload for this freighter is 2510 metric tons (2765 tons); the volume available is about 42 000 m³ (1.4x10⁶ ft³). The average cargo density can thus be about 64 kg/m³ (4 lb/ft³). One potential cargo container is a trailer-truck van which has a volume of about 63 m³ (2200 ft³) and an average cargo weight of about 23 metric tons (25 tons). On a weight basis this freighter can carry 110 vans of average cargo weight which would occupy about 65 percent of the main deck. In figure 9, the freighter has nearly half its payload in 48 average loaded truck vans and the remainder in about 300 stacked containers of density 128 kg/m³ (8 lb/ft³).

This freighter is "volume-rich"; it can carry partially filled containers without significant penalty; it can "clump" the containers in several areas leaving room for loading and unloading. In fact, it may be particularly suited to handle high volume-low density cargo, such as, automobiles at 96 kg/m³ (6 lb/ft³) or mobile homes at 64 kg/m³ (4 lb/ft³).

Containerization

For several years the shipping industry has been using the concept of cargo containerization. And with the advent of large cargo airplanes the air industry has also begun to look at it. Containerization is the use of standardized cargo containers that are interchangeable among different carriers - ship, truck, rail, and air. Presently, standard containers are 2.5 m by 2.5 m and 3, 6, 9, or 12 m long. (Trailer truck vans are about 2.5 m by 2.5 m by 10.7 m.) Their interchangeability is illustrated in figure 10.

Such containers greatly reduce the number of items handled and allow convenient transfer between land and sea or air carriers. Loading or unloading can be even faster if several containers are handled as one unit - using a pallet or rack. The loading or discharging of this NACV freighter using this technique is shown in figure 11. Containerization has impressively reduced expensive pier time and pilferage: a container ship in 1969 earned 3 to 4 times the revenue of a comparable break-bulk cargo ship (ref. 7). At least one terminal could (in 1969) load or discharge a container ship at a rate of 80 containers per hour (ref. 7).

The New York Port Authority has predicted that 70 percent of all containerizable cargo on the North Atlantic trade routes will move in container ships by 1973; 55 percent of containerizable cargo will be

moved in similar fashion between Japan and the U.S. East Coast. The growth of container trade on the U.S. West Coast is similar (ref. 7). The adaptation of air carriers to containerization is described in reference 13. Thus, it seems likely that by 1980 the technology of fast cargo turnaround will be fairly well developed.

Transfer

This freighter is suited to several types of cargo containers. One type is the standardized interchangeable container discussed in the section Containerization and illustrated in figures 10 and 11. This containerized cargo will usually be transferred by crane or conveyor system.

A second type of "container" is the self-propelled or towed vehicle, such as, a trailer truck van, automobile, or mobile home. This cargo could be transferred by crane, but, usually would be transferred in a roll on - roll off mode - like a ferry (fig. 12).

A third type of container is considered here, because it would be desirable to further reduce the dock time needed for cargo transfer. When loading, the more the cargo can be assembled and packaged before loading the shorter the load time will be. The cargo area of this freighter is arranged so that the entire payload could be preloaded onto large pallets or movable docks. The freighter would then operate in a "fork-lift" mode, moving under completely preassembled cargo sections (containers), or having them lifted aboard by cranes or having them towed aboard. In figure 13, the freighter is shown in this "fork lift" transfer mode. The cargo sections are supported by air cushion pallets and are readily towed on-board by a tractor.

DESIGN ASSUMPTIONS

The specifications of the NACV listed in Table I were derived using the following power and weight assumptions:

Power

Fan compression efficiency $\left(\frac{\text{ideal}}{\text{actual}} \text{ fan work} \right), \eta_f$	0.85
Thrust propulsive efficiency $\left(\frac{\text{jet thrust power}}{\text{thrust fan shaft horsepower}} \right), \eta_d$	0.50
Overall powerplant thermal efficiency $\left(\frac{\text{engine shaft}}{\text{reactor thermal}} \text{ horsepower} \right), \eta_t$	0.20
Cushion discharge coefficient	0.60

Drag at 50 m/sec in 2.6 m (average height) waves:

Aerodynamic	316 000 n	(71 000 lb)
Momentum	400 000 n	(90 000 lb)
Wave	129 000 n	(29 000 lb)
Trunk	610 000 n	(137 000 lb)
Other	205 000 n	(46 000 lb)

Thrust required at 50 m/sec cruise (in 2.6 m (average) waves)	1 660 000 n	(373 000 lb)
Thrust fan power required (rated)	169 MW	(227 000 hp)
Installed thrust fan power (rated)	211 MW	(284 000 hp)
Lift fan power required (rated)	34 MW	(46 000 hp)
Installed lift fan power (rated)	47 MW	(60 000 hp)
Rated total power at cruise	204 MW	(273 000 hp)
Installed total power, P_T	256 MW	(344 000 hp)
Reactor thermal power, $Q_R = P_T/\eta_t$	1280 MW	

Weight

Gross weight W_{GR}	4535 metric tons	(5000 tons)
Shield $W_{SH} = 10.5 \times 10^3 \sqrt{Q_R (MW)}$	375 metric tons	(415 tons)
Powerplant $W_{PP} = 0.907 \cdot P_T (hp)$ (2 lb per shaft horsepower)	311 metric tons	(344 tons)
Structure $W_{ST} = 0.175 \cdot W_{GR} + 24.5 \cdot \text{Plan Area (m}^2\text{)}$	1020 metric tons	(1130 tons)
Chemical fuel $W_F = W_{GR}(1 - e^{-\alpha})$	317 metric tons	(350 tons)

from Breguet range formula for chemically

powered aircraft: $\alpha = \frac{R \cdot \text{sfc}}{\frac{L}{D} \cdot V_0 \cdot 550 \cdot \eta_L}$

R = range (n. mi.)

sfc = specific fuel consumption (lb/hr/hp)

L/D = lift-to-drag ratio

V_0 = craft velocity (knots)

$$\text{Payload } W_P = W_{GR} - W_{SH} - W_{PP} - W_{ST} - W_F \quad 2510 \text{ metric tons (2765 tons)}$$

$$\frac{L}{D} = \frac{W_{GR} \cdot V_0}{326 \eta P} \quad 20.1$$

$$\text{where } \eta P = \eta_f P_{\text{Lift}} + \eta_L P_{\text{Thrust}}$$

TRANSOCEAN OPERATION

This freighter should be able to cruise at 50 m/sec through waves that average 2.4 m (8 ft) high (sea state 6). At reduced speed the freighter could negotiate - on cushion - waves about 8 m high. (In the North Atlantic, waves over 3 m high occur only about 20% of the time and over 6 m high about 10% of the time.) Because of the 7.6 m flexible skirt the freighter would have less severe structural stresses than the CAB concept. Its speed is a strong feature for the vehicle can outrun or go around storms. Thus, it could easily avoid areas where the waves would exceed 8 m or so. However, because of its size and seaworthiness the freighter could also go through storms; the vehicle would reduce its speed and follow the profile of the waves.

Reference 11, assumed an overall utilization (transit + dock time) of 7000 hours (of 8760 possible) per year for a 4500 metric ton CAB craft. The same utilization is assumed in this study. The remaining 1760 hours can be used for periodic overhauls and maintenance, such as skirt finger replacement. Now, if 75 percent of the 7000 hours is spend in transit (at 50 meters per sec) this freighter could make about 156 trips a year along a 6300 kilometer (3400 n. mi.) Atlantic route. With a cargo load factor of 0.6, it could carry more than 2.6×10^5 metric tons of cargo each year. By 1980, it would take a fleet of more than 250 such NACVs to move just 5 percent of the world's dry cargo. Thus, there is an incentive to study the economic and technical feasibility of NACVs.

PORT OPERATION

Although speed will be one of this freighters strongest points, economic operation will depend on efficient docking and cargo transfer. At 50 m/sec a transatlantic crossing would take about 34 hours. If a cargo vehicle is to operate economically, it must be unloaded or loaded in a time short compared to the travel time - say half a working day - about 4 hours.

Now, 25 percent of the 7000 hours utilization per year is assumed to be non-transit time; this would amount to about 12 hours per trip. Unloading and loading would take about 8 hours total. This would leave 4 hours

each crossing for taxiing between open sea and the terminal, for delays in crossing, and for minor servicing and repair that cannot be done while the cargo is being transferred.

Existing Ports

Although this transoceanic vehicle is radically new, it could use existing facilities. In a standard deep water port the freighter could remain on its cushion or it could settle into the water and behave as a displacement vessel. The maximum "draft" of the freighter would consist of a submerged, flexible 7.6 meter skirt and about 2 meters of rigid structure (flotation tanks, resting pads).

At maximum "draft" (no air cushion) the main cargo deck will be about 1.2 meters above the water surface (fig. 14(a)). As the cushion pressure increases, the main cargo deck will rise (figs. 14(b) and 14(c)). As the cushion pressure approaches 48 newtons per meter² (100 lb per ft²) the skirt will lift from the water and the cushion airflow will increase. The freighter will resemble a CAB craft until the skirt lifts completely from the water. With a cushion pressure of 48 newtons per meter², the main cargo deck will be 10.9 meters above the surface (fig. 14(d)). Thus, by varying the cushion pressure and airflow the height of the cargo deck can be adjusted. By matching cargo deck height with the dock height, roll on - roll off cargo or very heavy cargo can be more easily handled.

In harbor, the freighter could be maneuvered by its own power, or by tugboats, much like a ship. It could thus use existing ports and docks; no major port in the world should be necessarily closed to it because of its size or shape. A layout (fig. 15) of existing dock and terminal facilities shows modifications that might be needed for this ACV freighter. Extensive dock modification should not be necessary.

New Ports

An almost profound feature of this NACV is that it will not need a deep water port at all, because there need be no surface contact. This one characteristic makes much of the currently underdeveloped U.S. coastline geographically capable of being used as an ACV port. Much land that is now barren or unused or inaccessible would be cheap compared to urban land. (In Los Angeles the cost is about \$500 000 an acre close to the airport.) Cheap land would permit expansive docking facilities and terminals; it would permit distribution centers and industrial plants to locate close to the port.

Figure 16 is a layout of an inland city-port for NACVs. Because of the ACV mobility the trade areas of the city can fit into the natural

terrain. If the shore area should be preserved in its natural state, then the ports can move inland for miles to land that is presently undesirable for home sites or recreation or that is unimportant as a nature preserve.

An arriving transoceanic NACV would reduce its speed when it entered coastal waters. The freighter would have already reaped its speed benefit; it could afford to proceed more slowly - even for several miles inland. It would proceed to a shallow water dock or to an inland dock, by following a restricted land channel (fig. 16). The land channel could be water, pavement, grade, grass, or any other surface, which has solid obstacles less than 6 m high, deep gulleys less than 45 m wide, and long slopes less than 2.5 degrees.

The trade potential of the nuclear ACV could provide the economic "seed" for completely new communities as shipping trade did for the great seaports of the world. These new city-ports could become new population centers which would essentially increase the "economic living space" in the nation. For example, the Gulf Coast population is expected to increase by about 75 percent in the next 30 years. New places for people to live and work would be an important step toward decreasing urban congestion and increasing the quality of life.

Docking

This freighter can land or settle on a runway of concrete - much like at an airport. Once on the "runway" - with its own air cushion for support - the freighter could be maneuvered by two methods: (1) with its own controls or (2) with tractors. The first method would be a part of the overall maneuverability and hoverability of the vehicle - the deflection in the thruster slipstream. The second method - tractors - could develop from airplane experience.

Although this vehicle has a large side area (2200 m^2) and rests on a nearly frictionless surface - a cushion of air, wind gusts should not be a significant problem when docking because of the large inertia of the vehicle.

If it is not practical or desirable to build a solid runway, for example, in a marsh area, another inland docking concept might be used: the enclosed canal or swimming pool. In this concept the NACV would settle into a canal rather than on a runway. Once the NACV was floating in the canal it could from then on be handled with its own thrusters or as a ship in harbor - with tugboats.

TERMINAL

A familiar dock and terminal layout was shown in figure 15. But, figure 17 shows a modular terminal, designed especially to exploit the NACV freighter. As shown, the terminal module would have distribution areas for truck, rail, and air cargo, service facilities for the freighter, and sites for industrial plants. Industries, being so close to the terminals, could even use their own ACV freighters for their shipping and receiving.

Because the terminal could be built on any flat land at varying distances from the seashore the terminal would not have to be land limited. Similar terminal modules could be added on as needed. The modular concept is thus well suited for development of new dynamic cities (ref. 14) which would grow in chosen directions. For example, cities could evolve along a single line, multiple parallel lines, or even branch - as in figure 16. The mobility of the ACV freighter and its insensitivity to the surface over which it travels will help to encourage the shifting of trade and transportation centers needed as a new city grows.

Figure 18 shows the flow of containerized cargo along the automated conveyor system in the cargo distribution area of figure 17. The cargo would be automatically sorted at the intersections of the conveyor network. Ideally, a container would be picked up from an incoming vehicle, carried and placed directly on an outgoing vehicle, with no intermediate storage. Practically, for aircraft especially, the cargo would probably have to be partly assembled and sequenced before loading. The flow directions indicated, which are not optimized, emphasize the transfer of ACV cargo. For substantial cargo transfer among truck, railcar, and aircraft the flow pattern would be somewhat different.

This flow chart (fig. 18) suggests the cargo handling needed to ensure short dock times. Cargo handling and transfer to other carriers in such a terminal would be scheduled - just as airline passenger service is now scheduled to enable people to make connecting flights. Thus, the flow of cargo would resemble and follow a time schedule much like the flow of people.

CONCLUDING REMARKS

There is clearly a carrier gap in transocean commerce - ships are low cost and low speed; aircraft are high cost and high speed. The nuclear powered air cushion freighter described in this report could fit into this carrier gap - at intermediate cost and intermediate speed.

This freighter has a gross weight of 4500 metric tons, 50 percent of which can be cargo. From world trade forecasts, in 1980 more than 250 such freighters would be needed to haul just 5 percent of the world's dry transocean cargo. Thus, there is an incentive to determine economic and technical feasibility of such freighters.

The freighter is designed for and its usefulness is dependent on cargo containerization. The shipping industry is rapidly adopting this shipping concept and the air cargo industry is beginning to use it. Thus, by 1980 considerable experience should be available for applying the concept to air cushion freighters.

The development of this freighter depends on lightweight mobile nuclear reactor technology as well as air cushion vehicle technology. The payoff for uniting these two technologies could be great indeed - a large cargo vehicle that could cruise at 50 meters per second (100 knots) or just hover, supported solely by a cushion of air.

Use of the peripheral jet-flexible skirt air cushion concept would allow this freighter to go over waves nearly 8 meters high and solid objects 6 meters high. She would be a sea-worthy craft, capable of riding the high seas without her air cushion and docking at any major port in the world, much like a ship. But, by using air propulsion systems for thrust she also has an important, very different feature from ships - the freedom from surface contact. After crossing an ocean this freighter could continue inland to new, as yet uncreated, landlocked ports. The trade potential of a nuclear ACV could provide the economic "seed" for completely new communities as deep water shipping trade did for the great seaports of the world.

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TABLE I - SPECIFICATIONS FOR 4500 METRIC TON NUCLEAR POWERED ACV FREIGHTER

Chosen Operating Parameters	Gross Weight	4500 metric tons	5000 tons
	Velocity	51 m/sec (185 km/hr)	100 knots
	Base Pressure	48 n/m ²	100 lb/ft ²
	Daylight Clearance	0.3 m	1 ft
Dimensions	Length	137 m	450 ft
	Beam	76 m	250 ft
	Skirt Height	7.6 m	25 ft
	Cargo Space	} Main Structure Height	30 ft
	Plenum		4 ft
	Flotation Tank		6 ft
	Stabilizer Height		40 ft
	Vehicle Plan Area	9520 m ²	102 500 ft ²
	Flotation Tank Plan Area	4600 m ²	50 000 ft ²
Power	Total Shaft HP (cruise)	204 MW	273 000 hp
	Total Shaft HP (installed)	256 MW	344 000 hp
	Reactor Power	1280 MW	
	L/D	20.1	
Weight	Shield	375 metric tons	415 tons
	Powerplant	311 metric tons	344 tons
	Structure	1020 metric tons	1130 tons
	Chemical Fuel Reserve	317 metric tons	350 tons
	Payload	2510 metric tons	2765 tons
Chemical Reserves	Range		500 n. mi.
	Specific Fuel Consumption		0.4 lb/hp/hr
Cargo	Weight	2510 metric tons	2765 tons
	Volume	42x10 ³ m ³	1.4x10 ⁶ ft ³ (a)
	Number of Containers ^b (max)	110	

^aIn nautical terms the gross weight of this ACV would be 14 000 tons; the dead-weight would be 2765 tons.

^bOne average container is assumed to be 2.5 m by 2.5 m by 10.7 m (63 m³) and weigh about 23 metric tons (25 tons) (1 average trailer truck load).

OCEANBORNE TRADE FORECAST

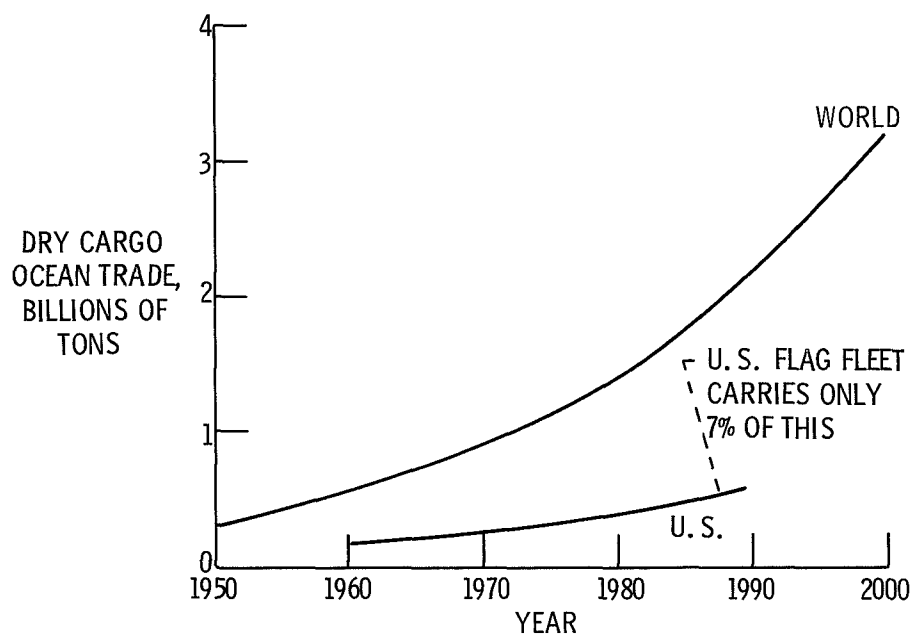


Figure 1

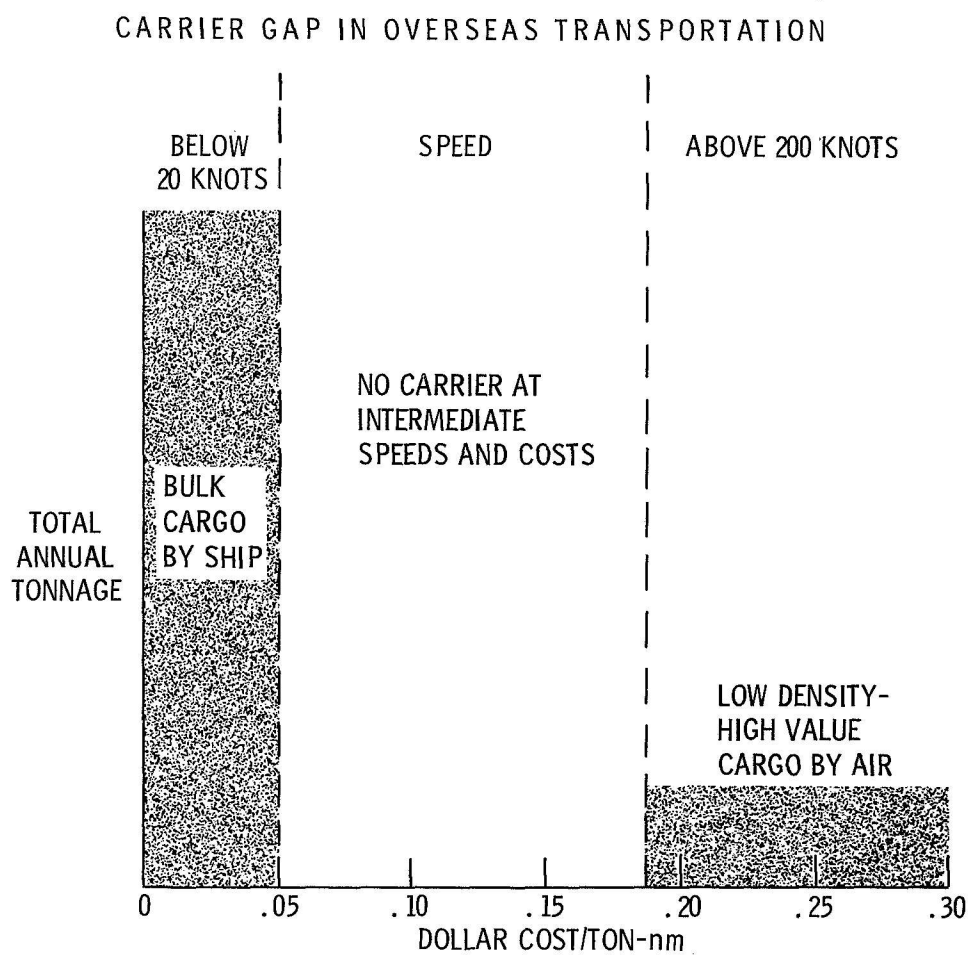


Figure 2

BRITISH HOVERCRAFT LTD. SRN-4 AIR CUSHION VEHICLE

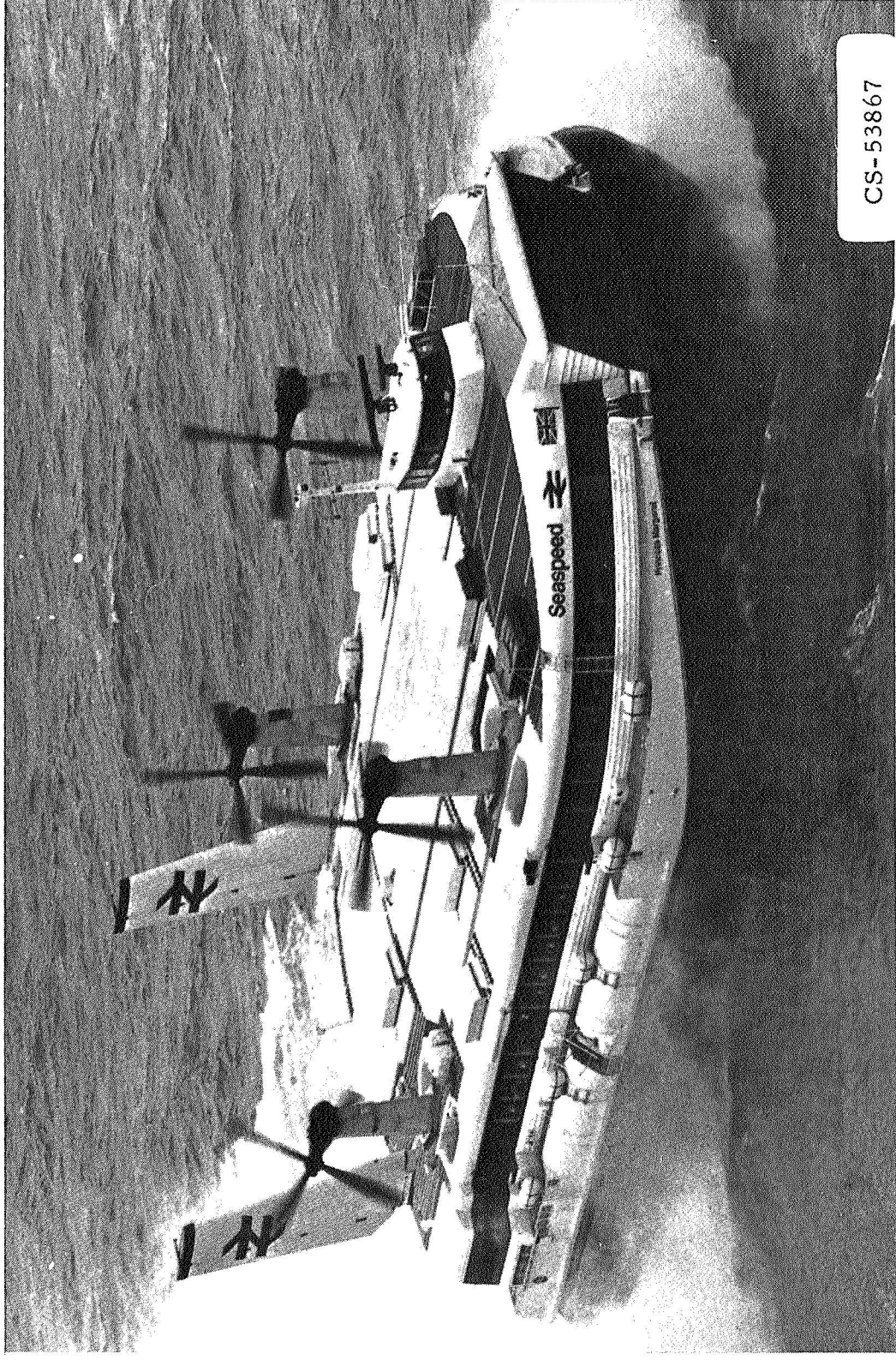


Figure 3

BELL AEROSYSTEM SURFACE EFFECT SHIP



Figure 4

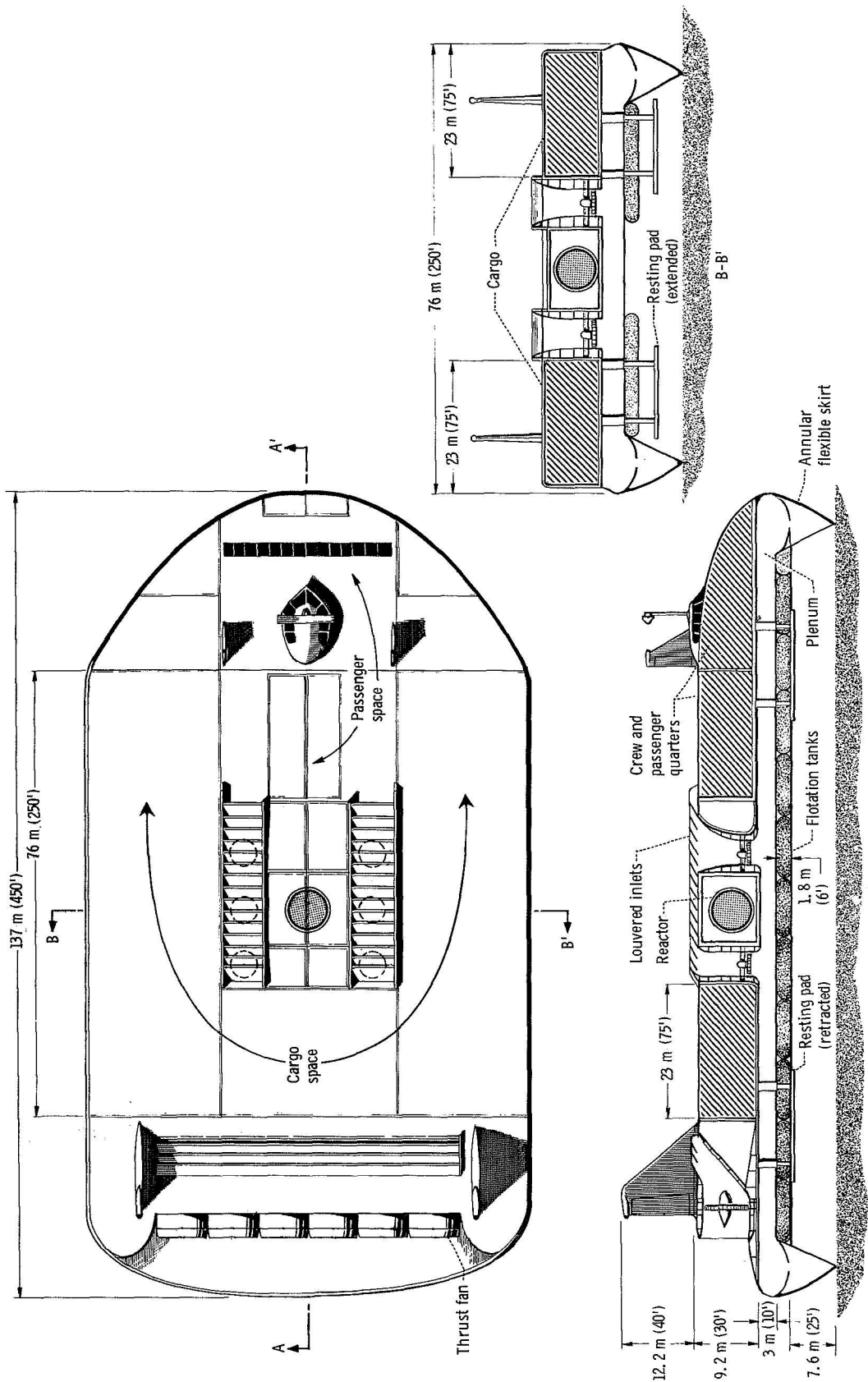
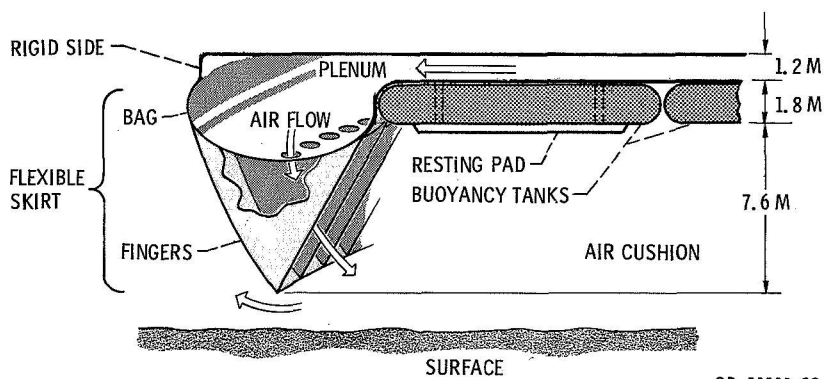
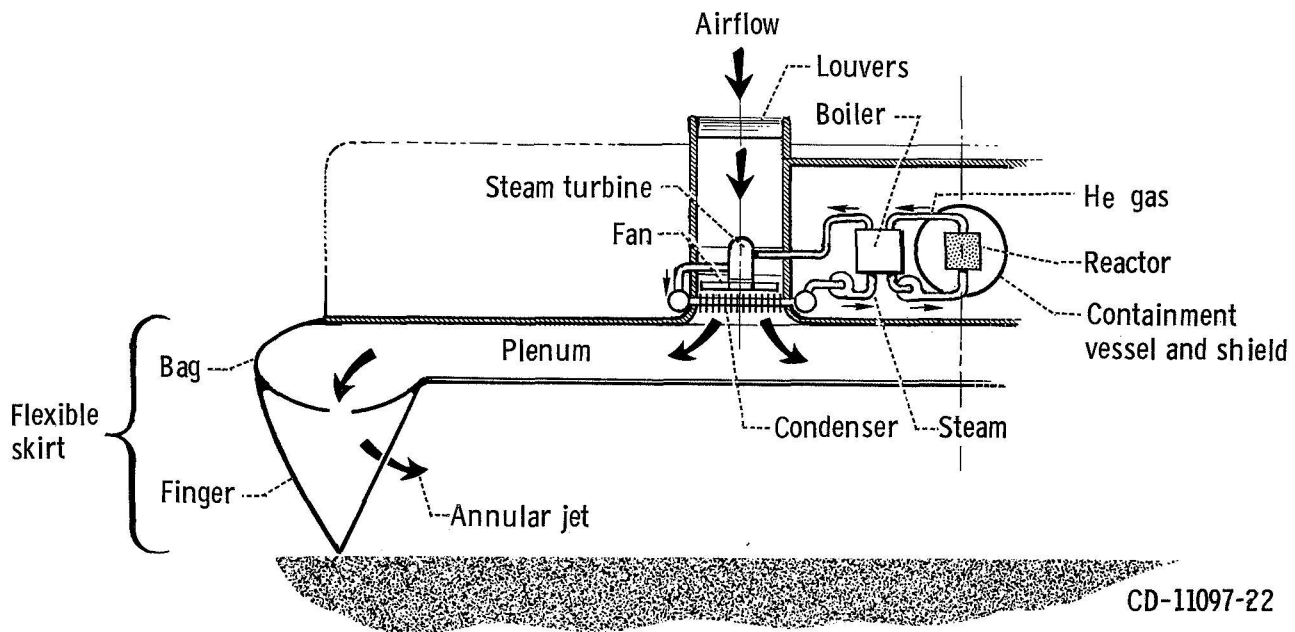


Figure 5. - Schematic drawings of 4500 metric ton ACV freighter.



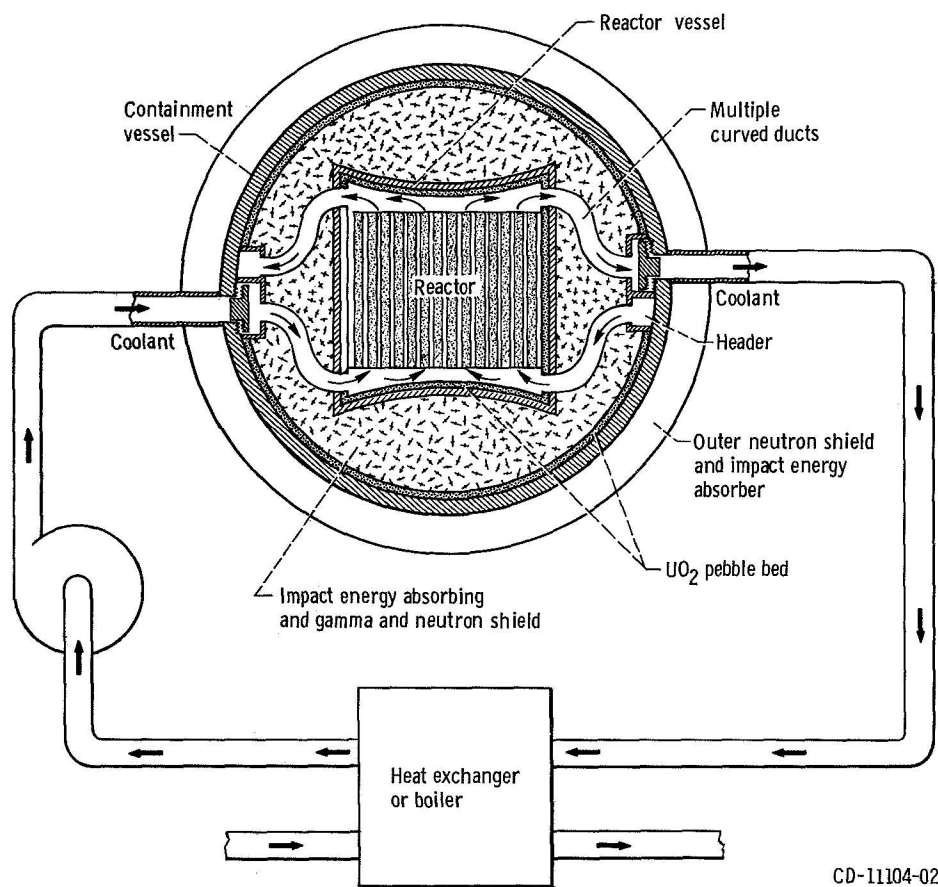
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Figure 6. - Cutaway view of airflow through flexible skirt.



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Figure 7. - Schematic drawing of steam turbine drive for lift fan.



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Figure 8. - Schematic drawing of a helium cooled reactor for mobile applications.

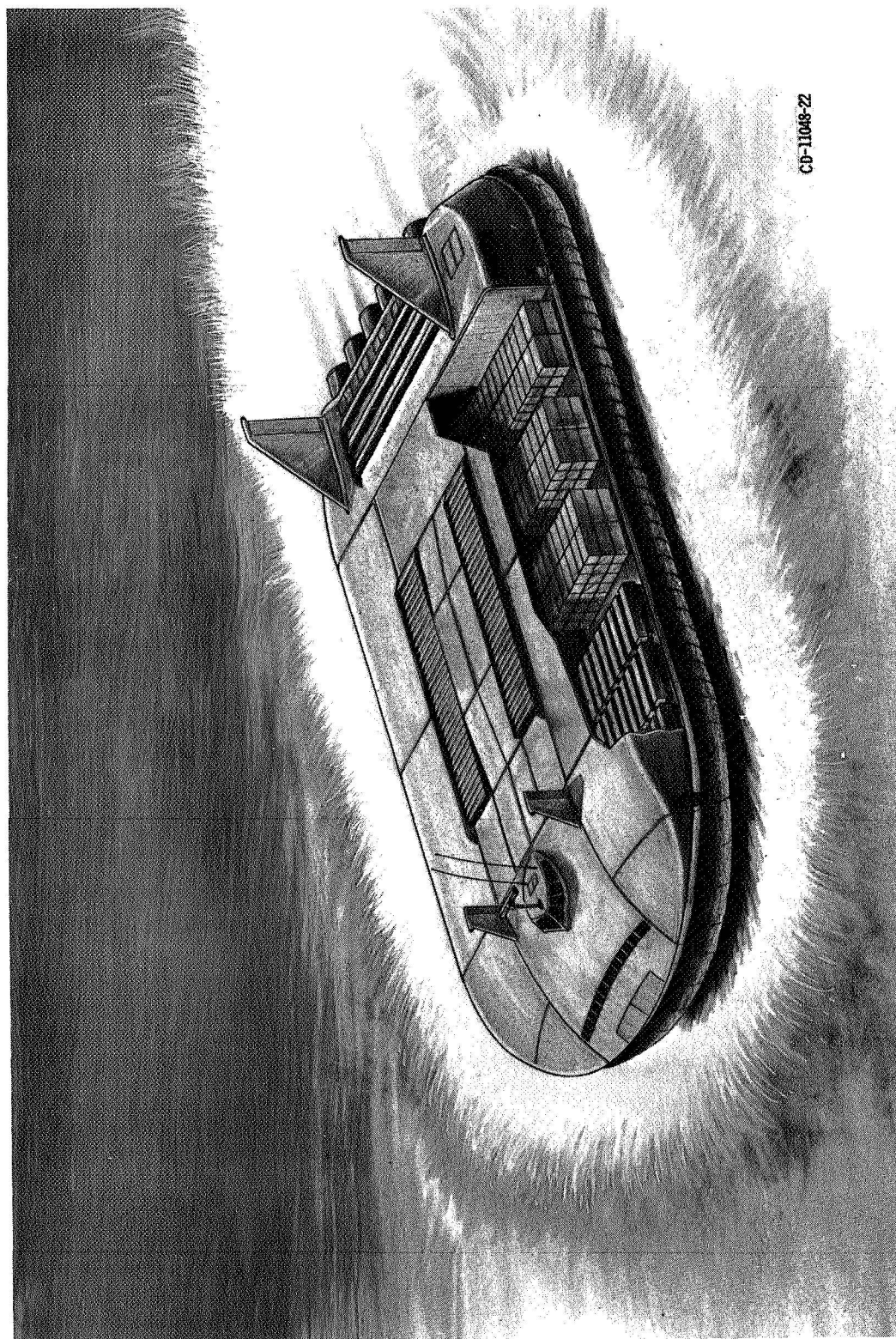


Figure 9. - 4500 Metric ton nuclear ACV freighter.

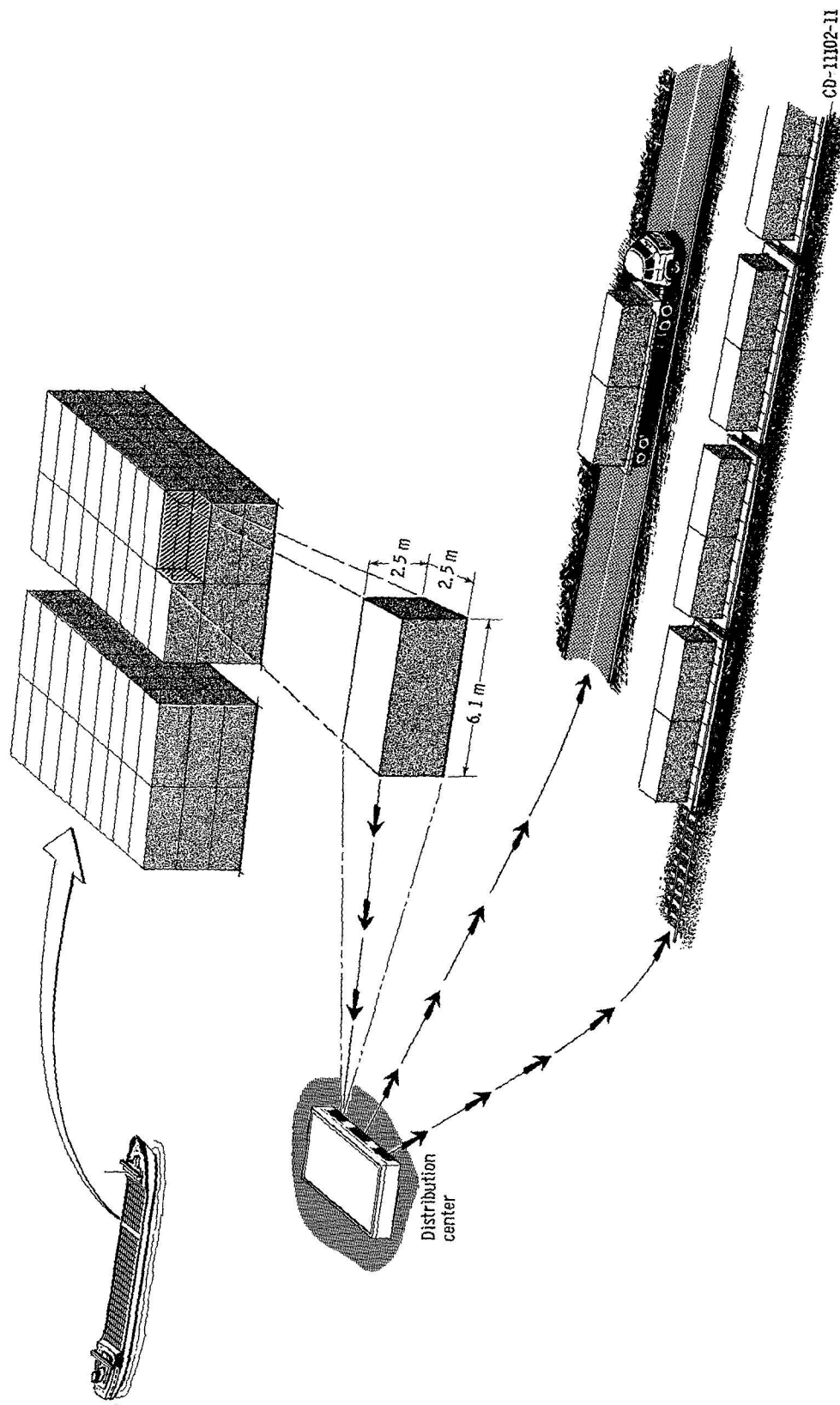


Figure 10. - Standardized intermodal container.

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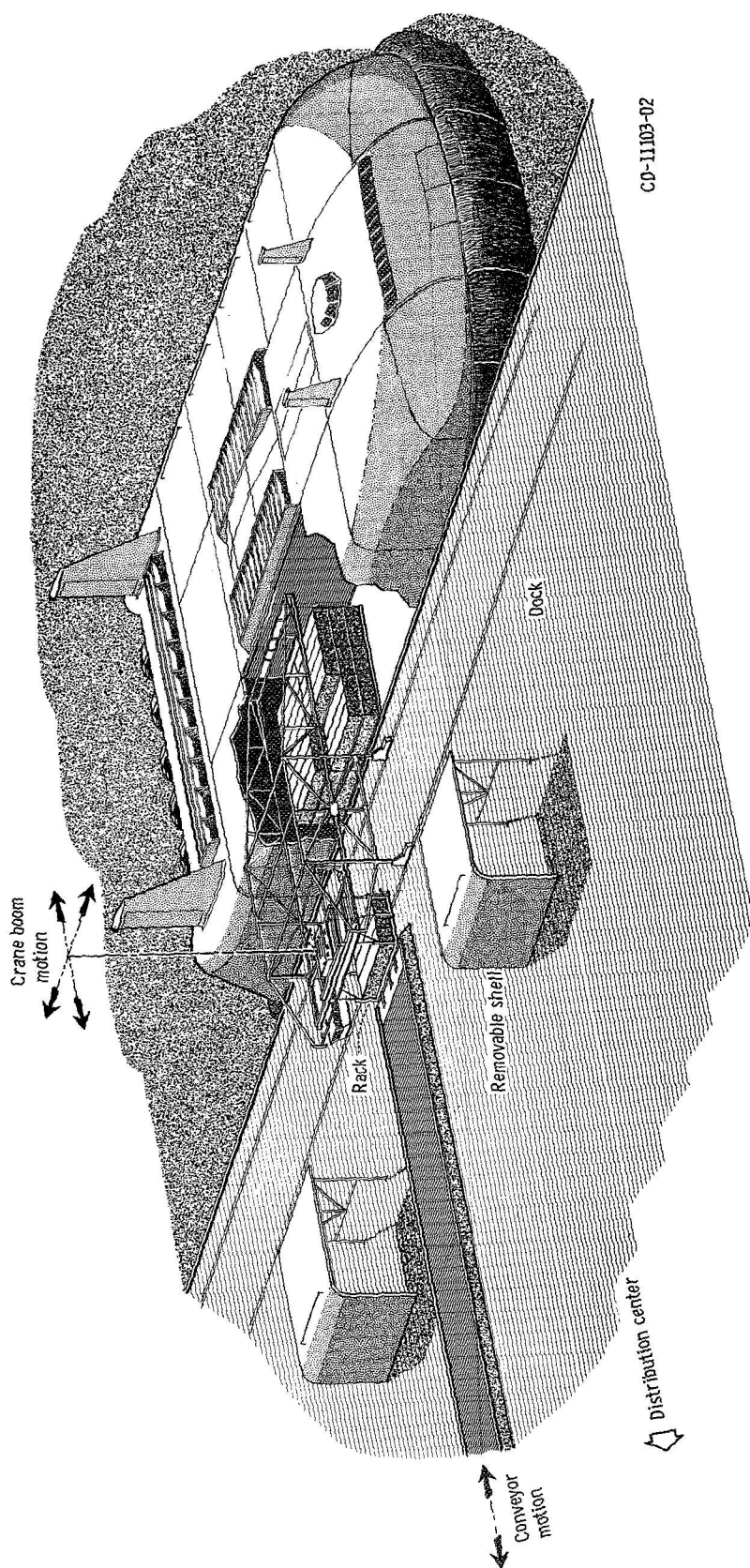
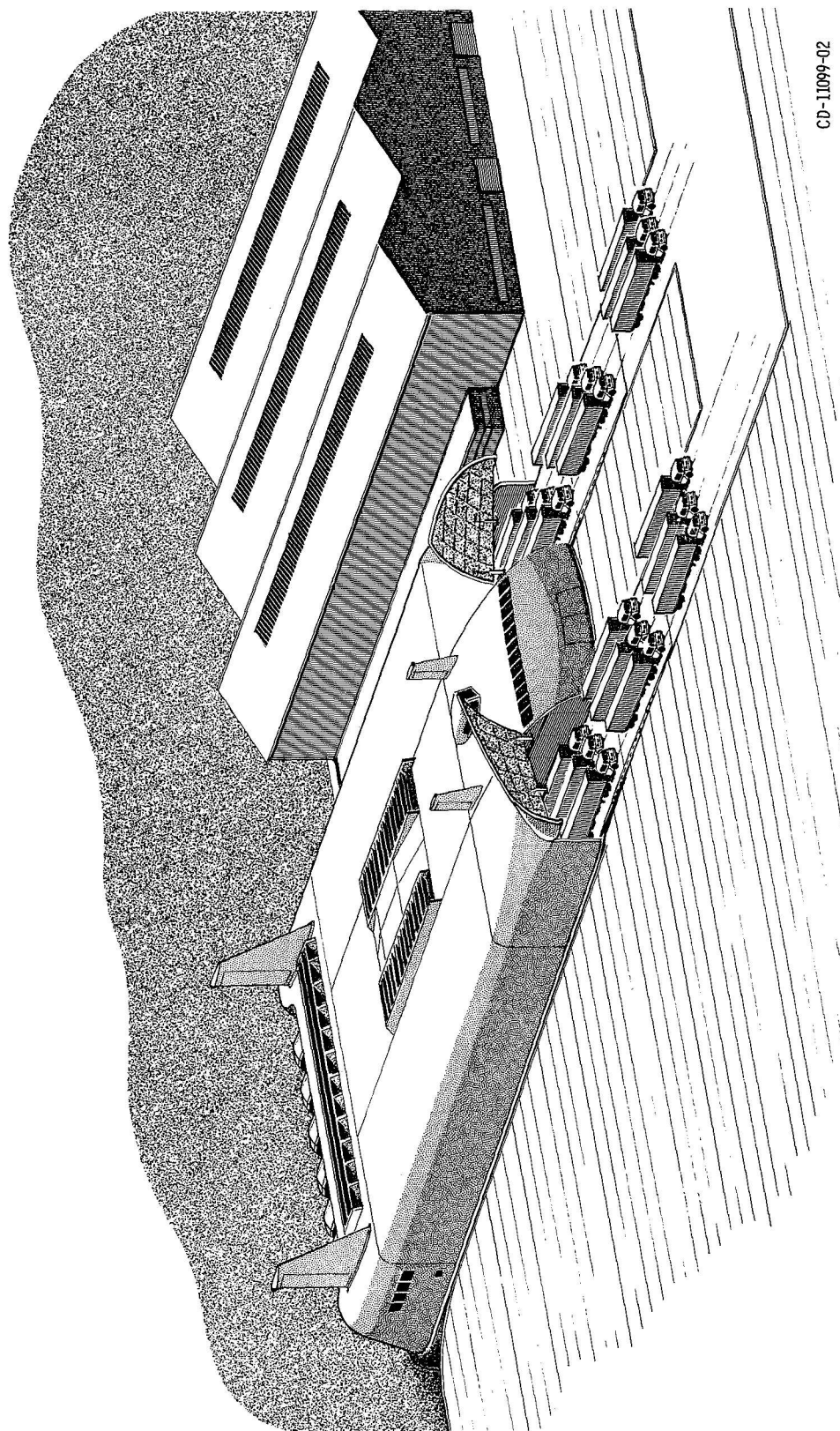
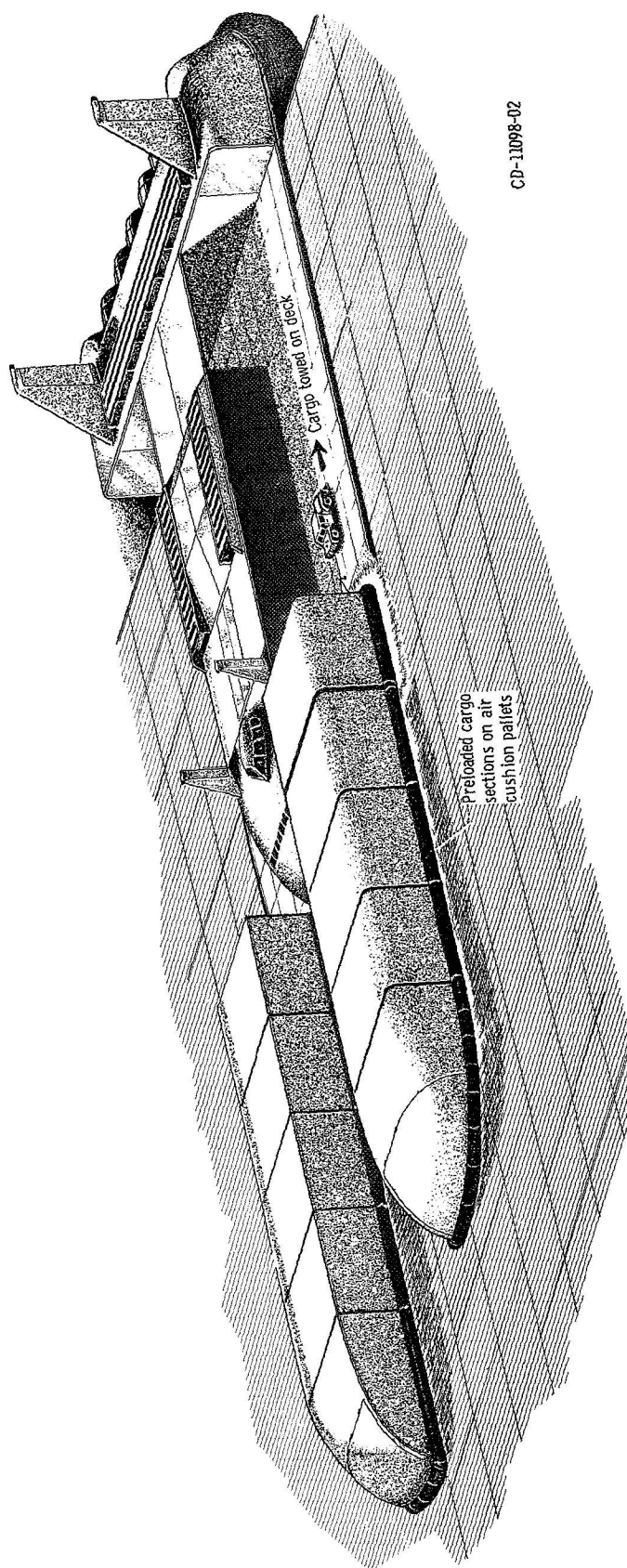


Figure 11. - ACV freighter in containerized cargo transfer mode.



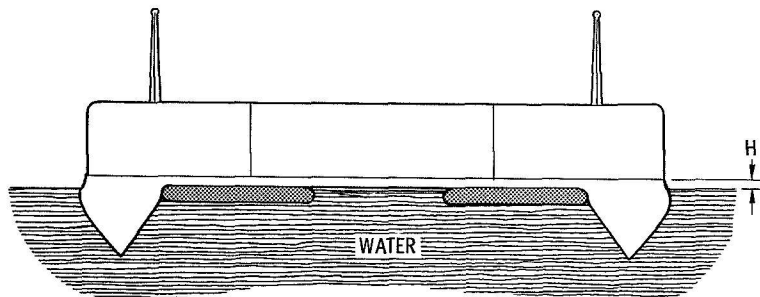
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Figure 12. - ACV freighter in roll off cargo transfer mode.

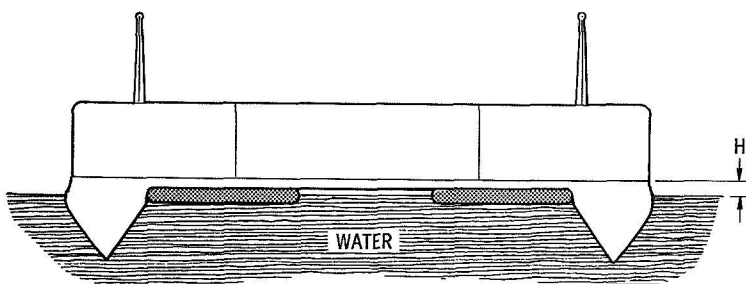


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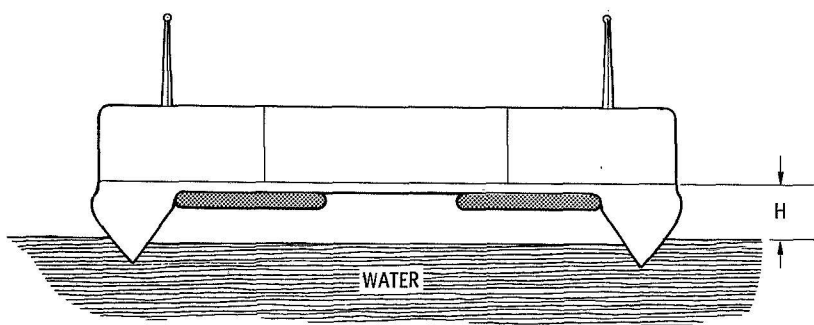
Figure 13. - ACV freighter in "fork-lift" cargo transfer mode.



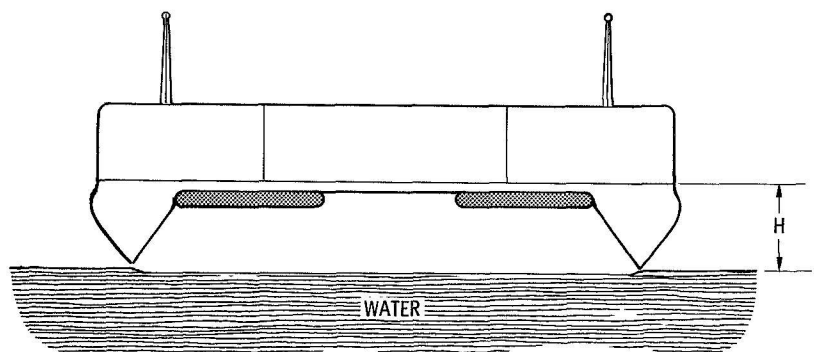
(A) NO AIR CUSHION
DECK HEIGHT (H) = 1.2 m
(DISPLACEMENT VESSEL MODE).



(B) CUSHION PRESSURE $\approx 24 \text{ N/m}^2$
DECK HEIGHT $\approx 2.1 \text{ M}$.



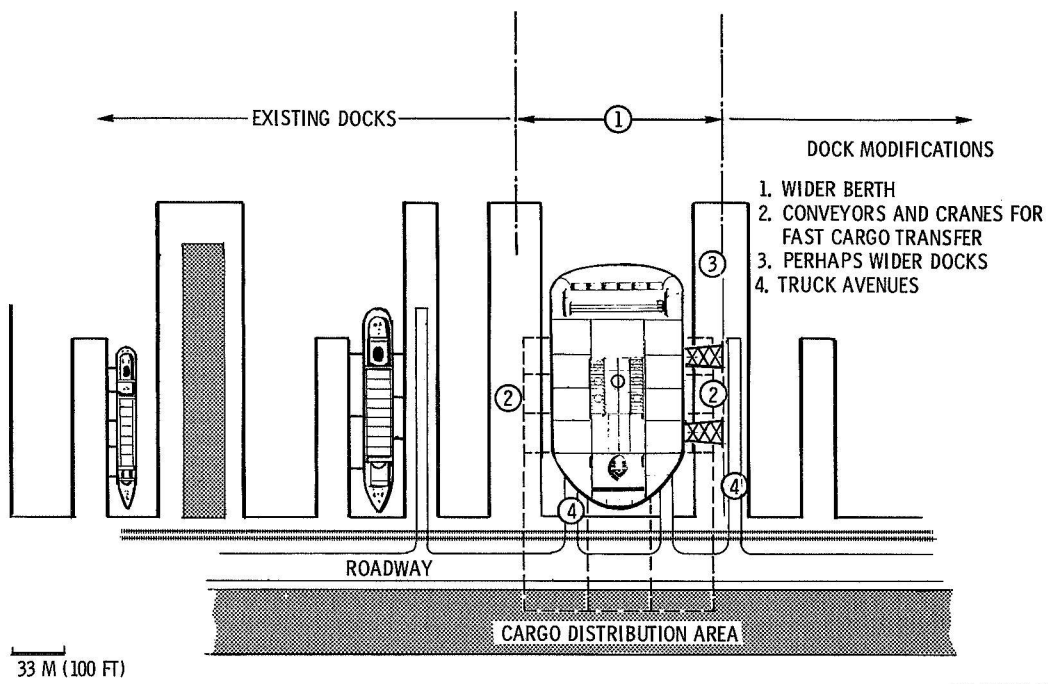
(C) CUSHION PRESSURE $< 48 \text{ N/m}^2$
 $3.0 \text{ M} < H < 10.9 \text{ M}$
(CAPTURED AIR BUBBLE MODE).



(D) CUSHION PRESSURE = 48 N/m^2
DECK HEIGHT = 10.9 M
(PERIPHERAL JET MODE).

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Figure 14. - ACV freighter with cargo deck at various heights.



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Figure 15. - Existing shipping docks with ACV modifications.

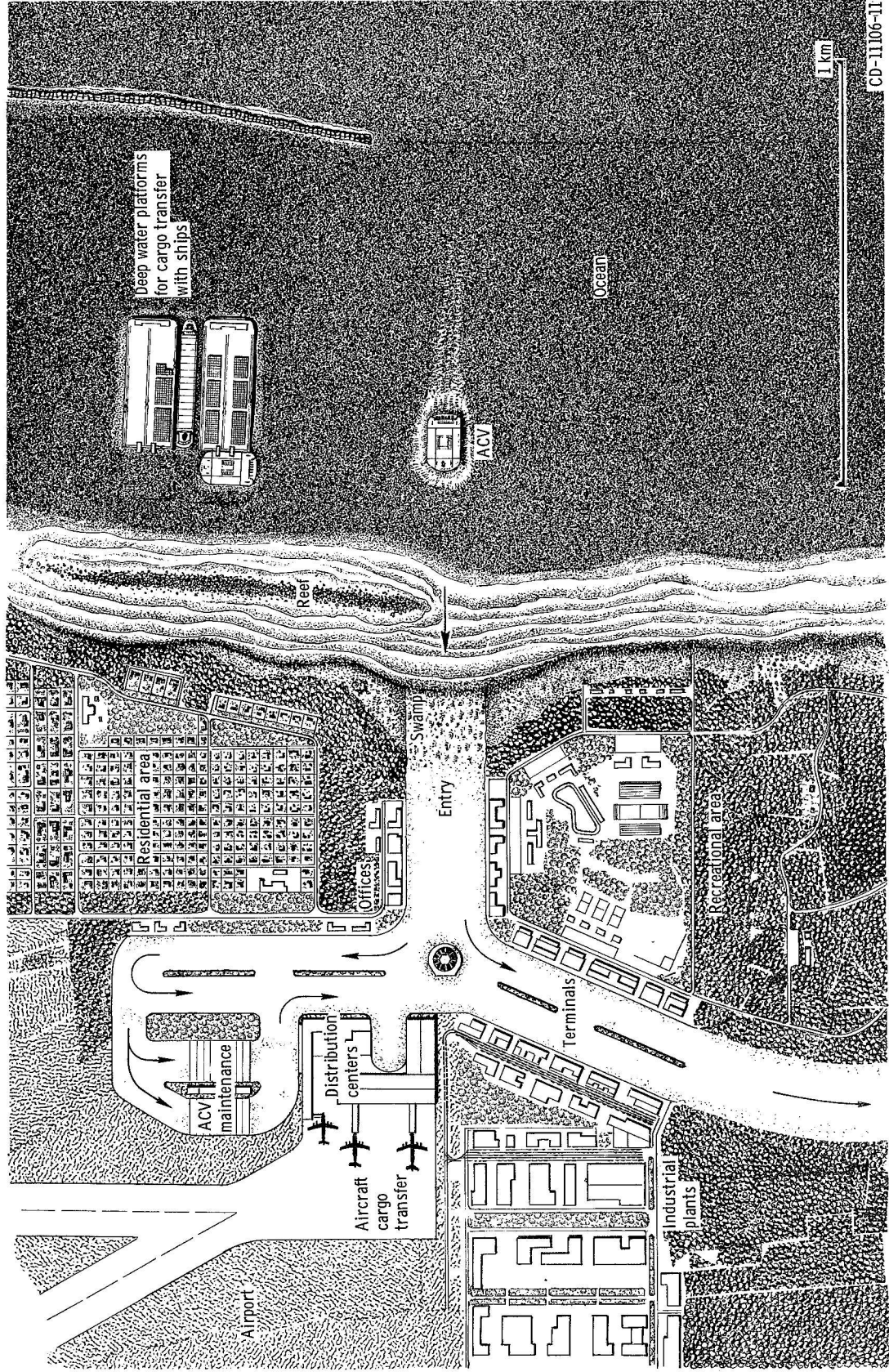


Figure 16. - City-port for nuclear ACV freighters.

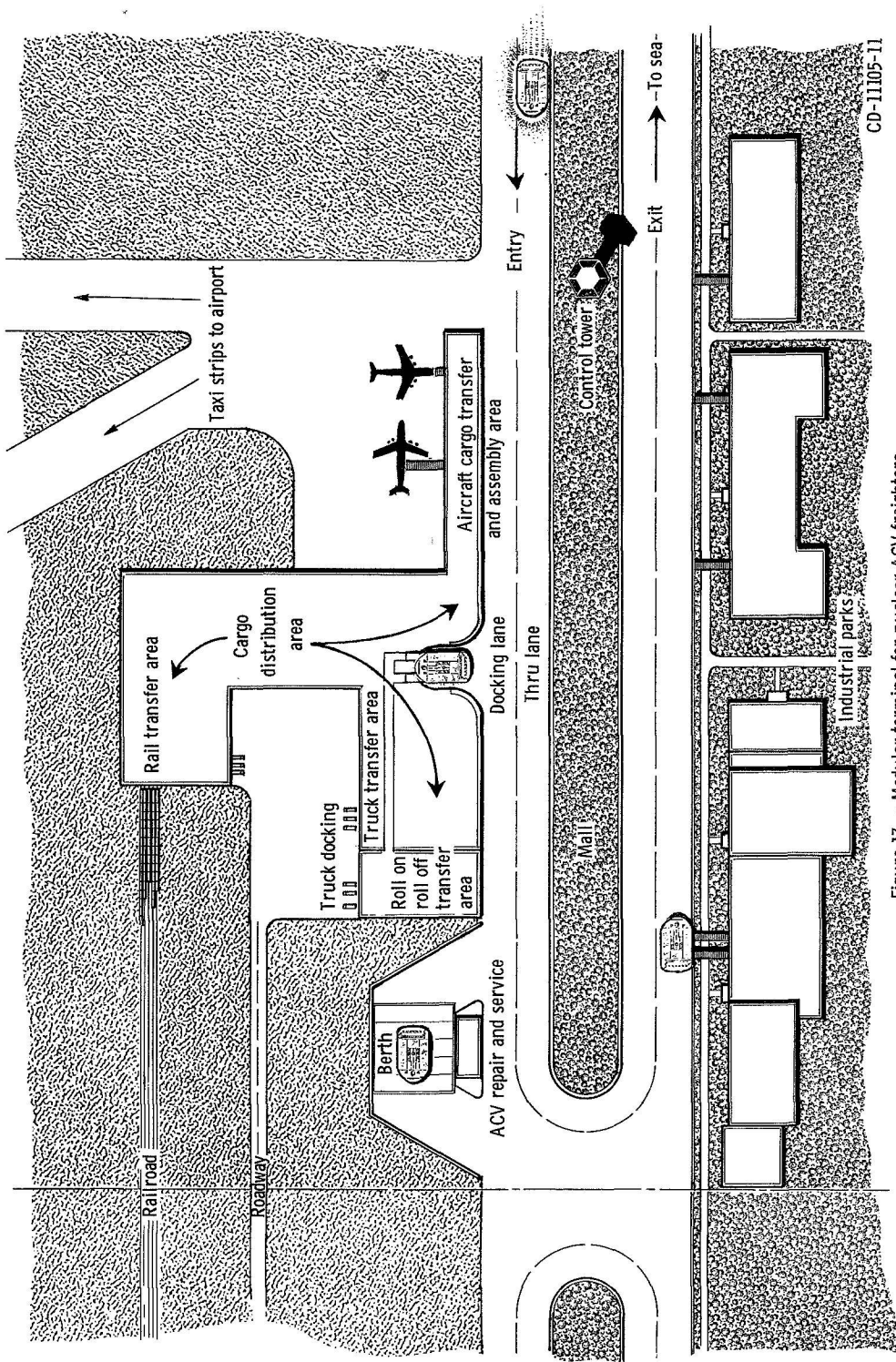


Figure 17. - Modular terminal for nuclear ACV freighters.

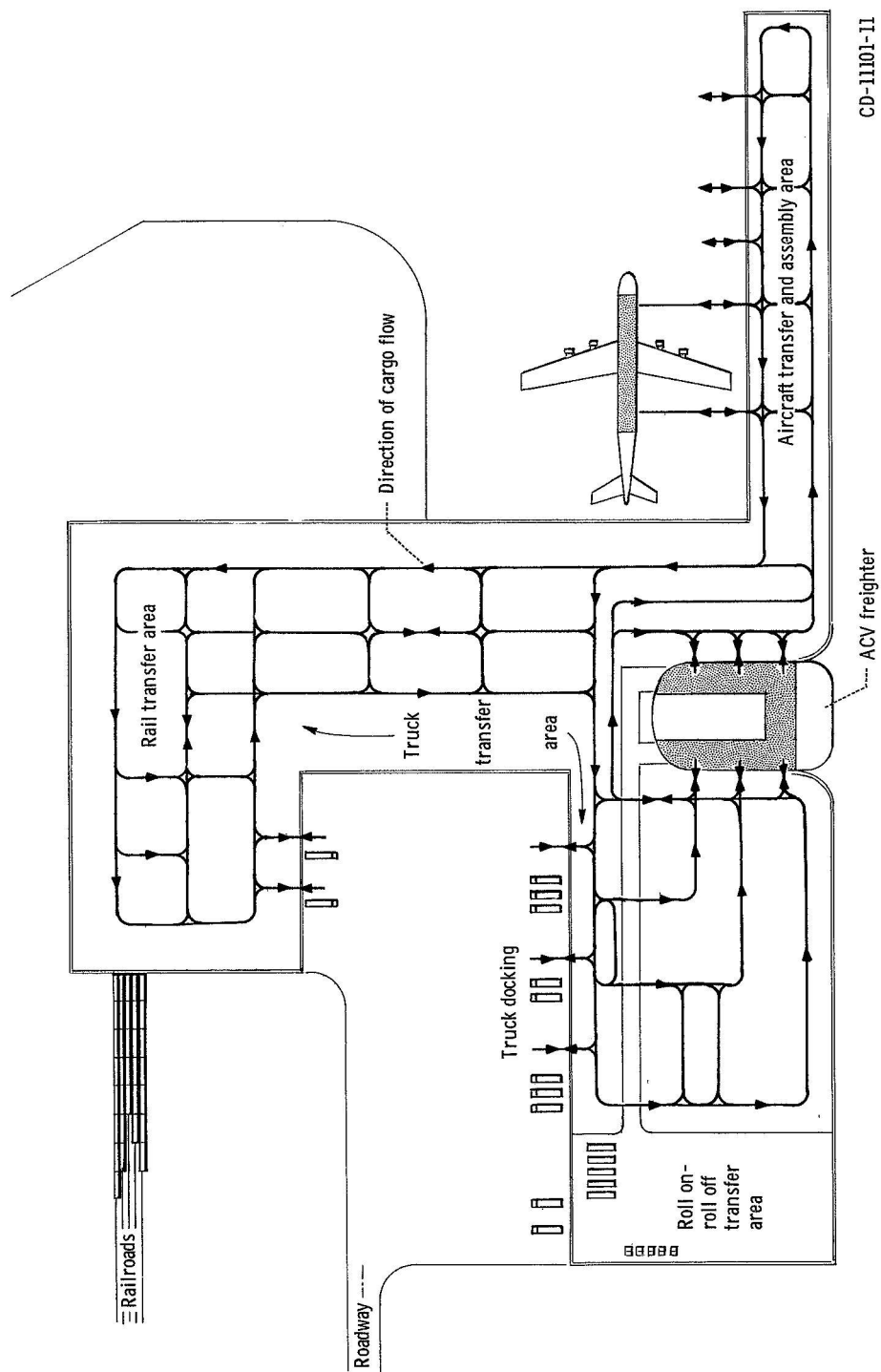


Figure 18. - Cargo flow in cargo distribution area of figure 17.